Emerging SSL Markets for General Illumination

DOE Solid-State Lighting Workshop

April 23-24, 2007

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Strategies Unlimited

Outline

- Introduction
- Markets
- Lighting
- Outlook

HB LED Market Analysis

- Market is worldwide in scope
  - Main production and consumption are in US, Europe, Japan, Taiwan, S. Korea, China, SE Asia
- Market analyzed in terms of packaged devices (lamps, SMDs, multichip, high-power packages)
- Materials include InGaAlP (red-orange-yellow) and InGaN (blue, blue-green, green, white)
  - Higher performance, “qualified” devices
- Market segmented and sub-segmented by applications that have similar functionality

HB LED Application Segments

Other
Indicators, small displays
amusement, misc. other

Mobile Appliances

Illumination

HB LED Market

Signs and Displays

Signals

Automotive

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HB LED Market Trends

- Market continued its “slow growth” phase in 2006 – similar patterns to 2005
- Overall market growth was 6% to $4.2 billion
- Heavily influenced by ongoing decline in mobile phone market
- Other applications continued to have attractive growth rates
- Substantial ASP erosion across many product types

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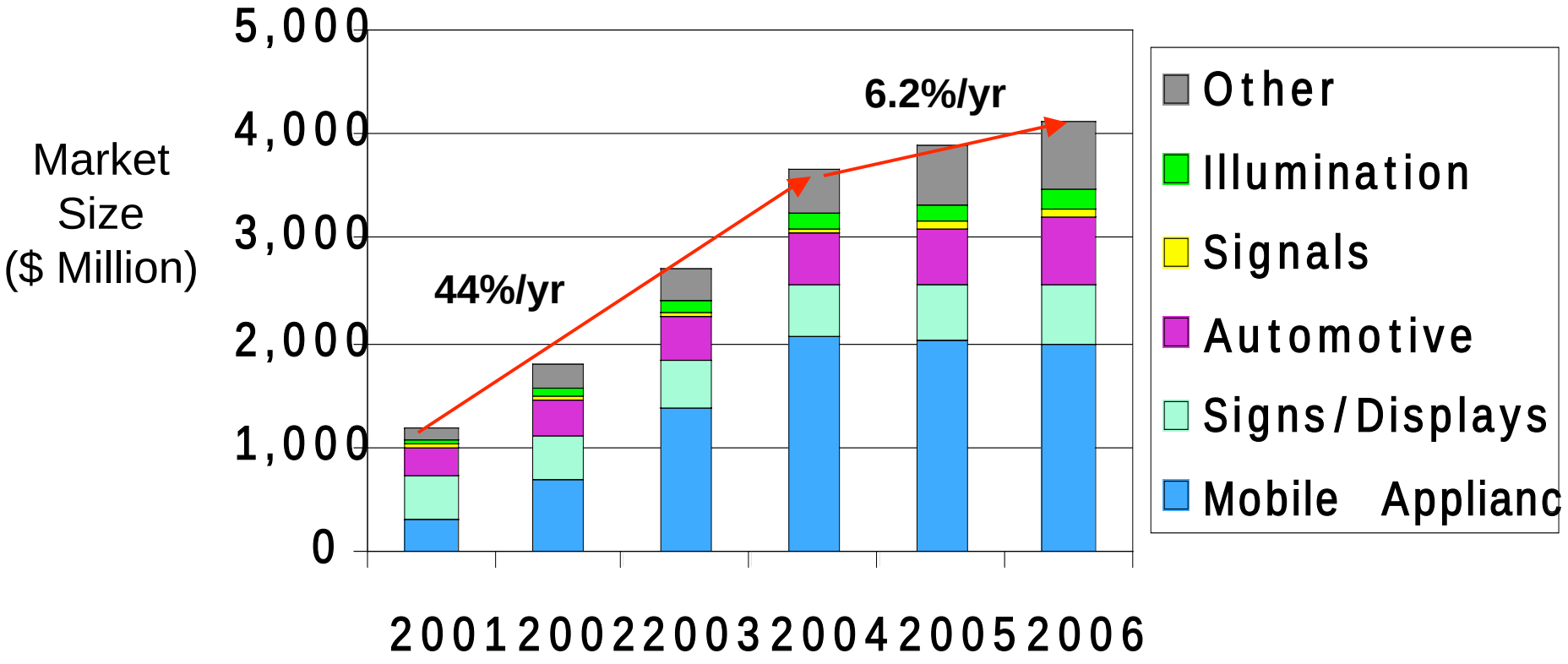
Recent Market History



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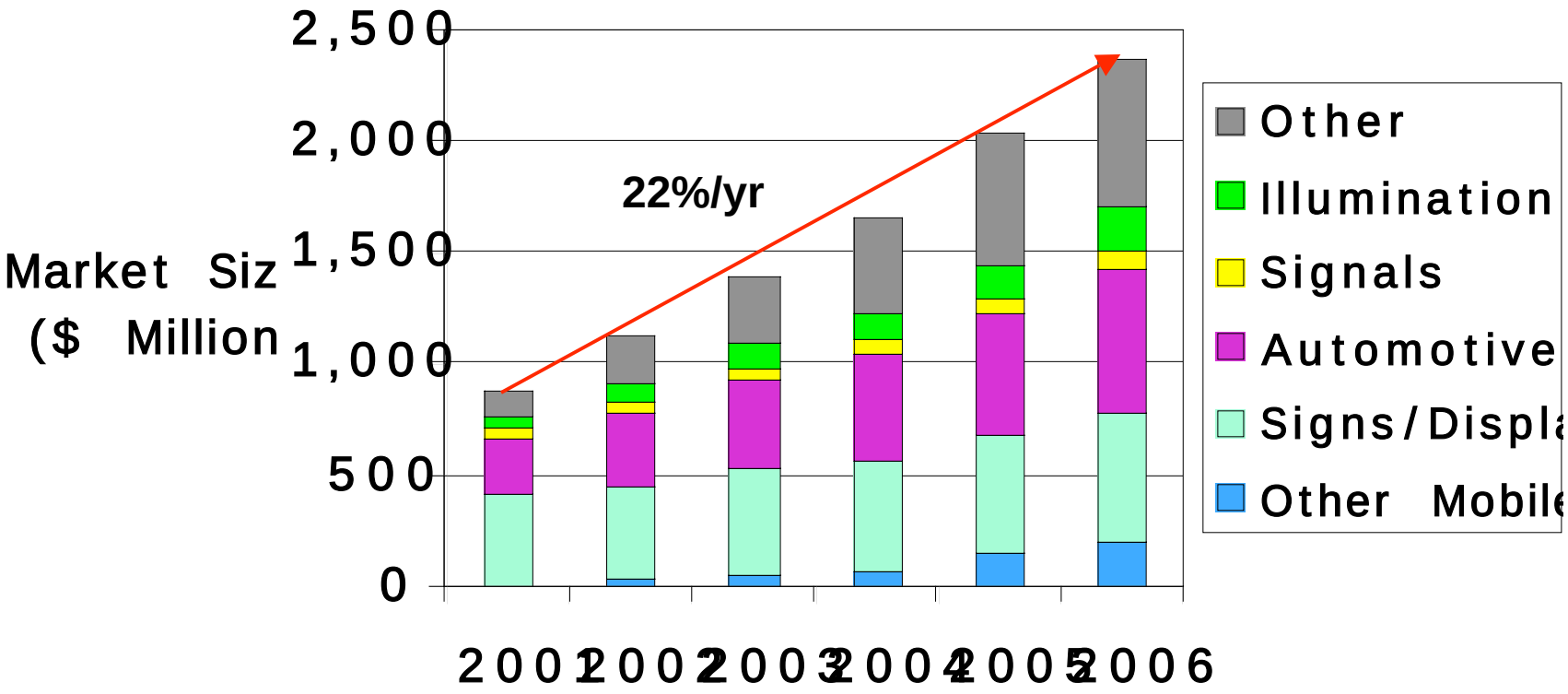
Market Growth Without Mobile Phones



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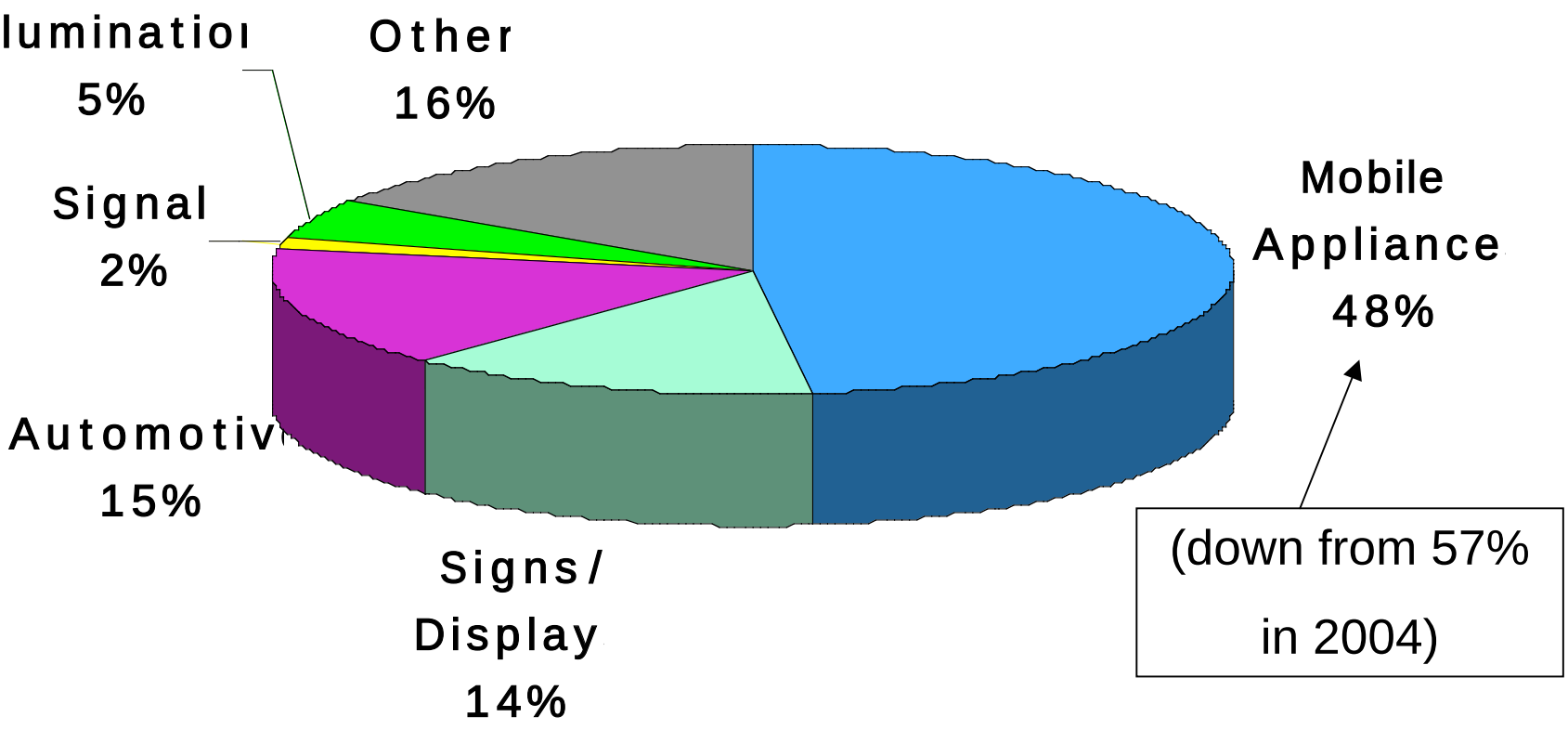
2006 Market by Application



Total: $4.2 Billion

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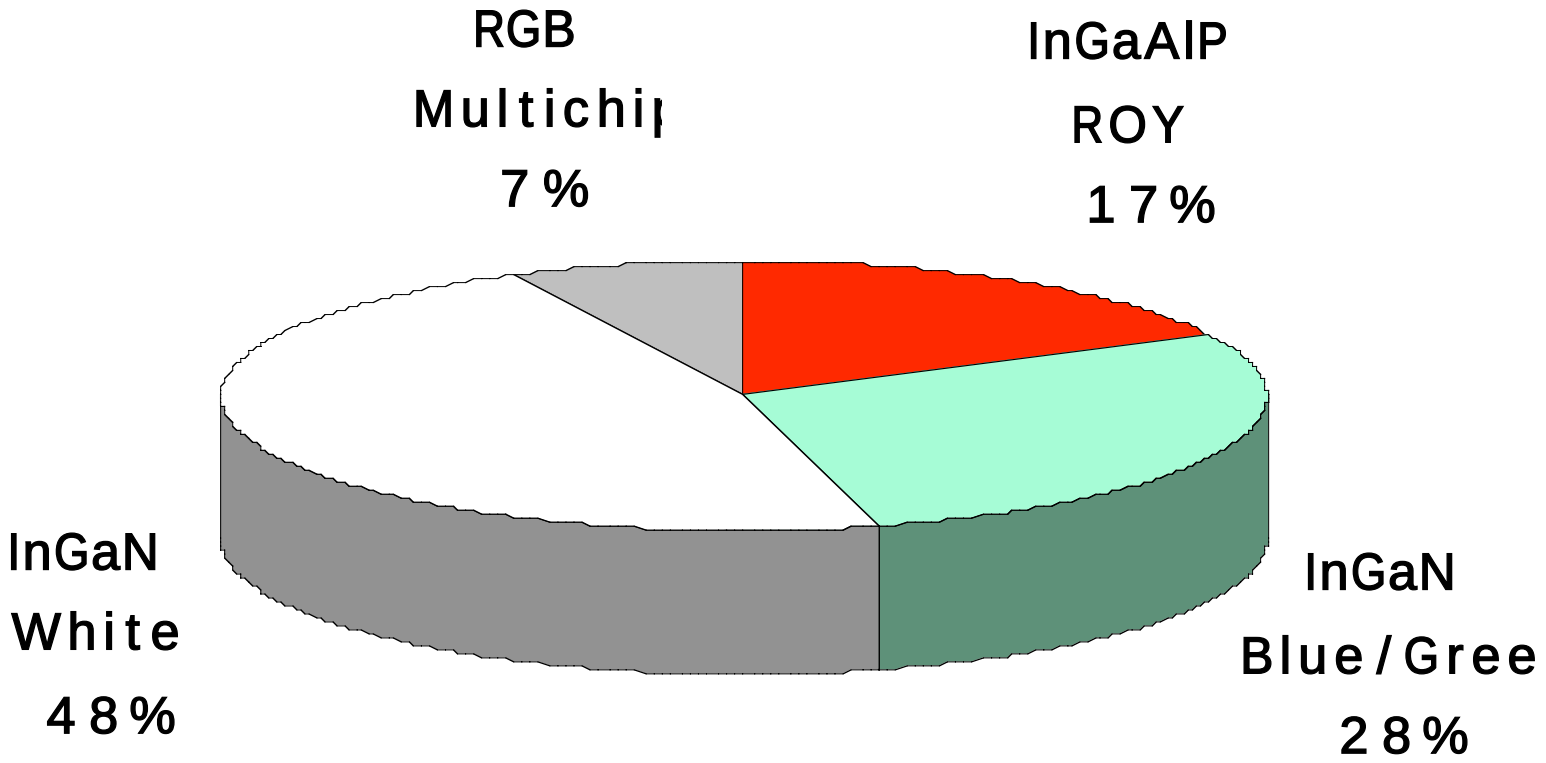
2006 Market by Color



Total: $4.2 Billion

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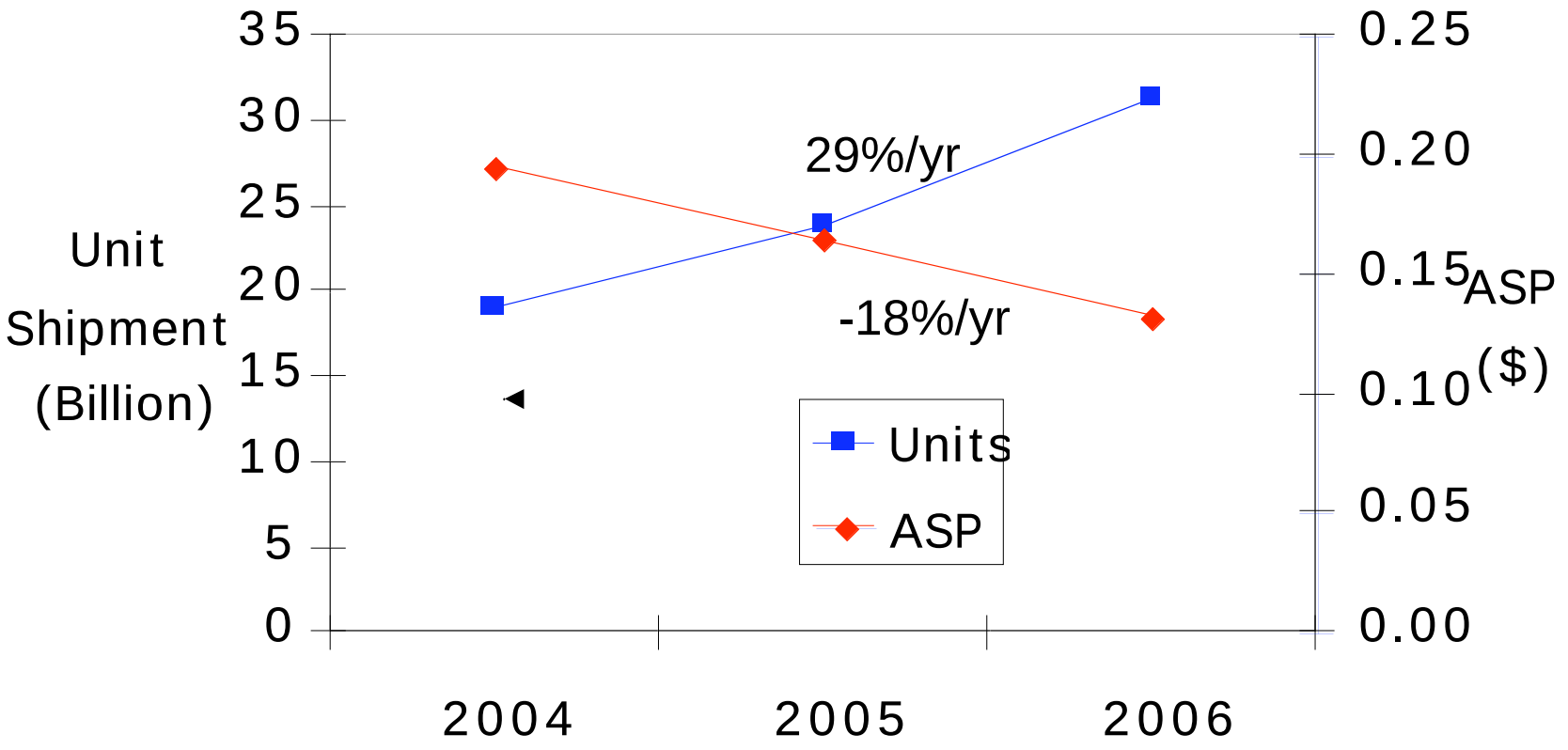
HB LED Units and ASPs



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Solid-State Lighting Market

- The use of HB LEDs for lighting is currently the fastest growing application
- The market is highly fragmented, encompassing many niche applications
  - Architectural lighting is the largest
  - Most applications are for colored (R,G,B) light
  - General illumination applications are starting to emerge
- Hundreds of companies worldwide are participating at the luminaire or fixture level
  - Strategies Unlimited has identified and described approximately 300 such companies, but there are more
  - Participants range from start-ups to the world's largest lighting companies

HB LED Lighting Market

- The 2006 market for HB LEDs used in lighting was $205 million
  - Architectural is the largest
- Growing at around 37% per year – the highest of any HB LED application
- Projected to reach ~$1 billion in 2011
- Majority of applications use RGB today, but white will increase to more than 60% of the market by 2011

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Status of SSL Fixture Industry

- Many small companies dedicated to SSL; high level of LED expertise
- Many large and medium lighting companies, with some interest in SSL, offer a few products
  - Most lack in-house LED expertise
  - Rely on outside consultants for design, prototyping
- Volumes are small and costs are high, independent of high cost of LEDs
- Products in the market are highly variable in terms of quality

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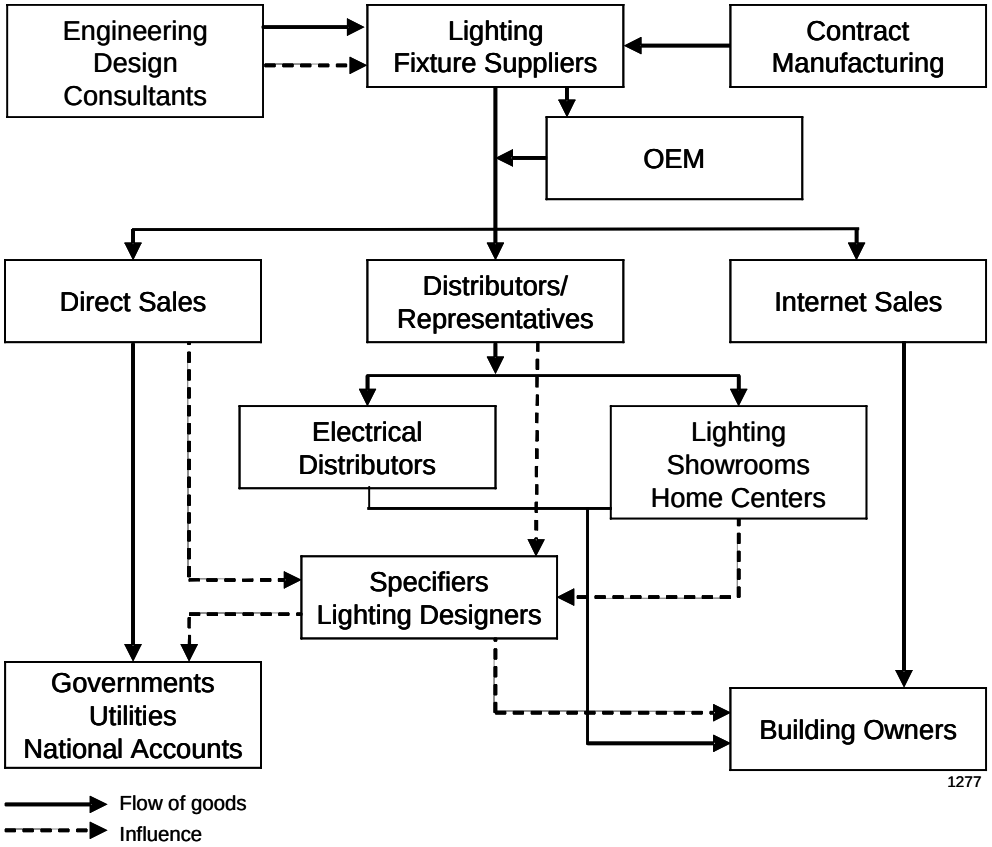
SSL Market Development

- Most product and market development is being carried out by small, specialized companies
  - With a few exceptions, e.g. Philips Lighting, Zumtobel
- Generally, large lighting fixture company interest ranges from zero to modest (but interest is growing)
  - In-house LED expertise is minimal
  - European companies moving faster than US
- Large companies control the access to sales and distribution channels and customers

Structure of the Lighting Fixture Industry



SSL Market Drivers

- Visual appeal
  - Saturated colors, near point source of light, design flexibility
- Long lifetime
  - Applications with high maintenance costs
- Compact form factor
- Lack of radiated heat
- Low-voltage operation
- Energy efficiency
  - Colors, low wattage applications (e.g. battery and solar powered), low temperature operation

10 Significant Near-Medium Term Applications

- Architectural
- Channel letter/contour lighting
- Consumer portable (e.g. flashlights)
- Residential
- Machine vision
- Retail display
- Entertainment
- Safety/Security
- Outdoor area
- Off-grid (generally solar-powered)

Interesting Emerging General (White) Lighting Applications

- Retail Display
  - Lumination (GELcore)
  - Stylmark
  - OptoLum
  - MAG-LED
  - Nualight
  - Color Kinetics
  - Bartco
  - Matsushita Electric Works
  - Philips
- Residential
  - Permlight
  - LLF
  - Lemnis
  - Progress
  - Renaissance
  - Bruck

Retail Display Lighting

- White LEDs are being used to provide attributes that are advantageous for certain types of products:
- High-end retail (e.g. designer label branded stores)
  - "High-tech" look; interesting effects; design flexibility
- Cosmetics
  - Lack of radiated heat from source
- Jewelry
  - Sparkling appearance from point light source; compact; long life
- Refrigerated display cases
  - More efficient than linear fluorescents at low temperatures; rapid start-up; long lifetime

Retail Display Lighting Examples

Source: Hera GmbH

Source: Nualight

Source: MAG-LED

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Refrigerated Display Case Success Story

- Wal-Mart adoption of LED refrigerated display case lighting from GELcore was the SSL “story of the year”
- Installing in all new Sam’s Club and SuperStores from Dec. 2006, ~300 per year in US
  - Part of the Wal-Mart’s “green” strategy
- Drivers are energy and maintenance savings
  - Can use occupancy sensors to turn off lighting during low traffic periods (impossible with fluorescent due to slow start-up)
- Other supermarket chains are likely to follow Wal-Mart’s lead

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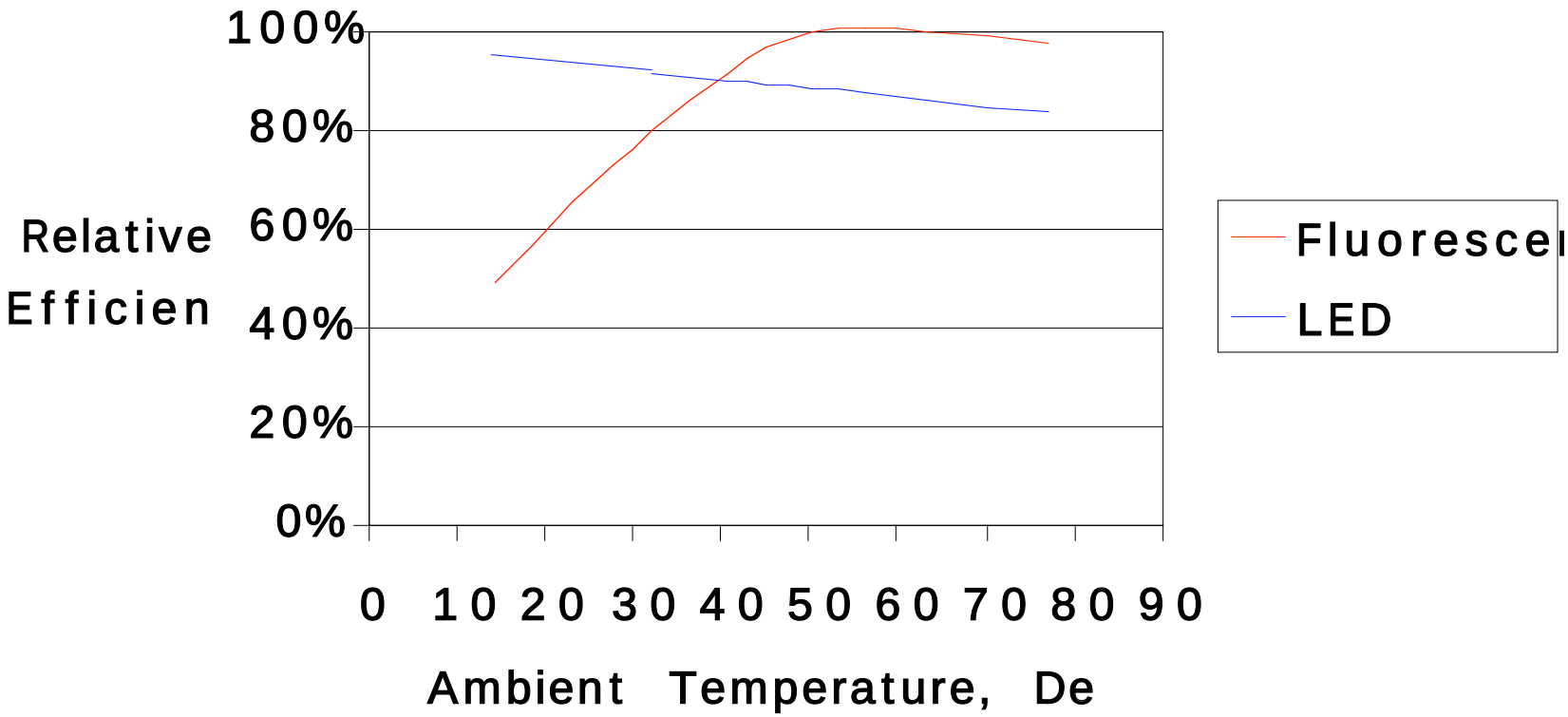
Linear Fluorescent vs. White LED Relative Efficiency



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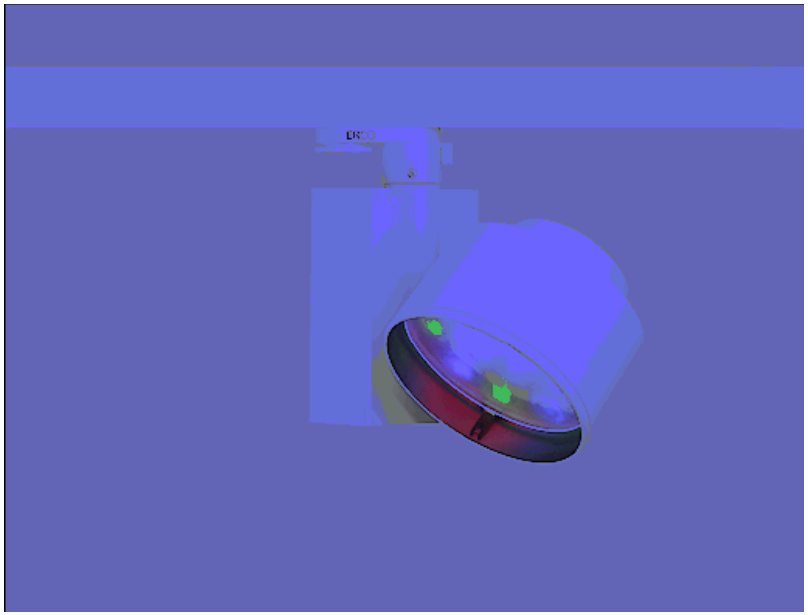
LED lighting fixtures – a wide variety in the market

LED Lighting Fixtures (1)

Source: Altman

Source: Lighting Services Inc./TIR Systems

LED Lighting Fixtures (2)



Source: ERCO

Source: Hera GmbH

LED Lighting Fixtures (3)

Source: Lucesco

Source: Herman Miller/Fuseproject

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LED Lighting Fixtures (4)

Source: Bronzlite

Source: Cosmos Ignite Innovations

LED Lighting Fixtures (5)

Source: Elletrica Rotaliana srl

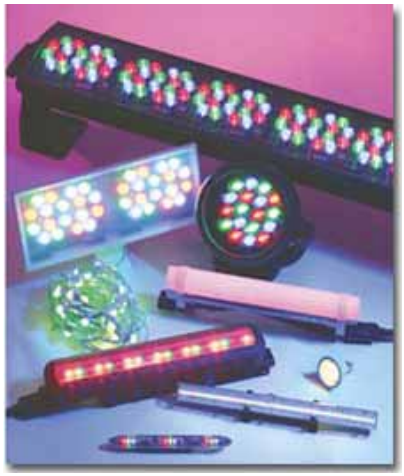
Source: Progress Lighting

LED Lighting Fixtures (6)

Machine Vision

Channel Letters

Source:
Color Kinetics



Source:
Philips Lighting

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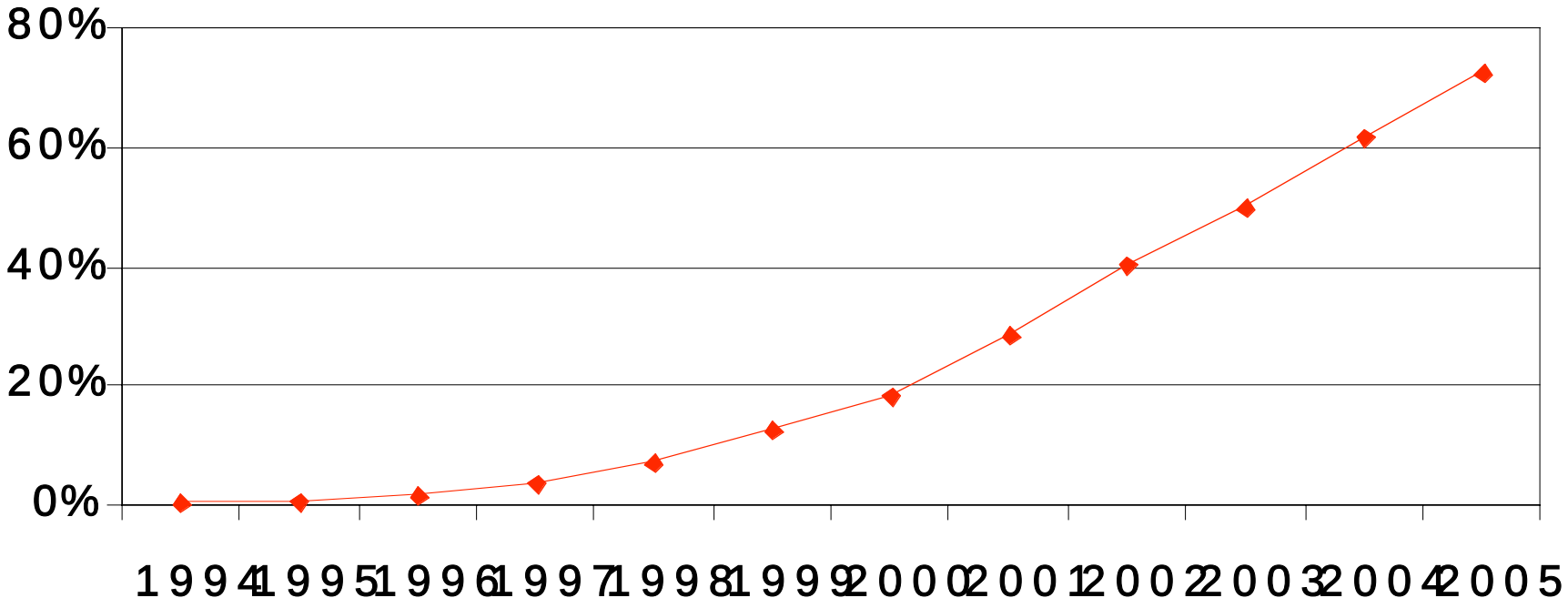
Opportunities for SSL

- Offer a unique lighting solution
- Create an aesthetically pleasing lighting environment
- Deliver value (on a cost-of-ownership basis)
- Provide lighting products adapted to unique physical environments
- Save energy; comply with regulatory requirements (e.g. Title 24 in California)

Challenges for SSL

- High initial cost
- Other alternatives for energy efficiency
- Consistency of color/binning issues
- Need to provide a complete lighting solution with ease of installation
- Adapt to standard electrical interfaces and controls
- Realistic claims of performance
- Development of standards
- Need widespread base of lighting fixture designers and engineers who understand LEDs
- Need for high-efficiency light engine/fixture design

North American Red Traffic Signal Market Penetration – Percent of Installed Base



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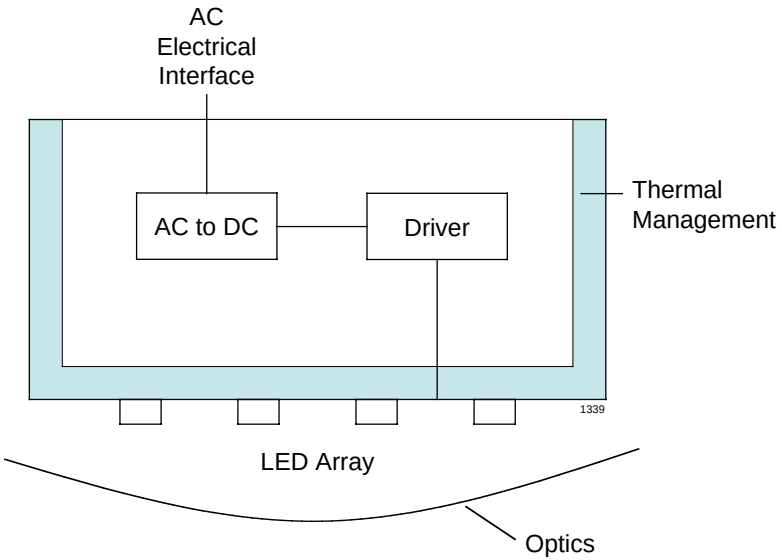
What is the Competition?

Light Engines - 2007

Incandescent R30
$3
655 lm/65 W

CFL R30
$6
750 lm/15 W



LED
~$100
600-650 lm/11-15 W

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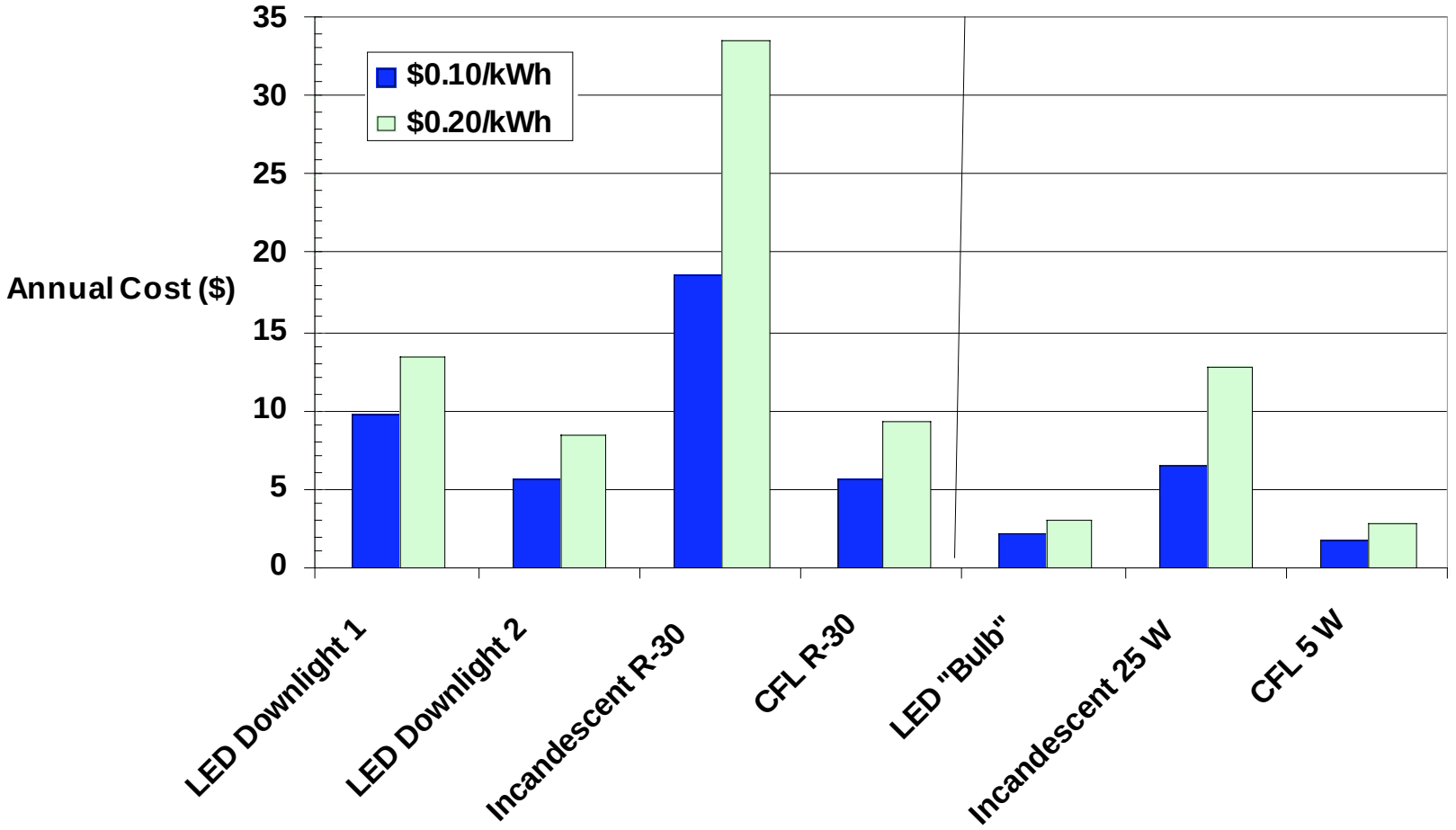
Annual Cost of Lighting (Today)



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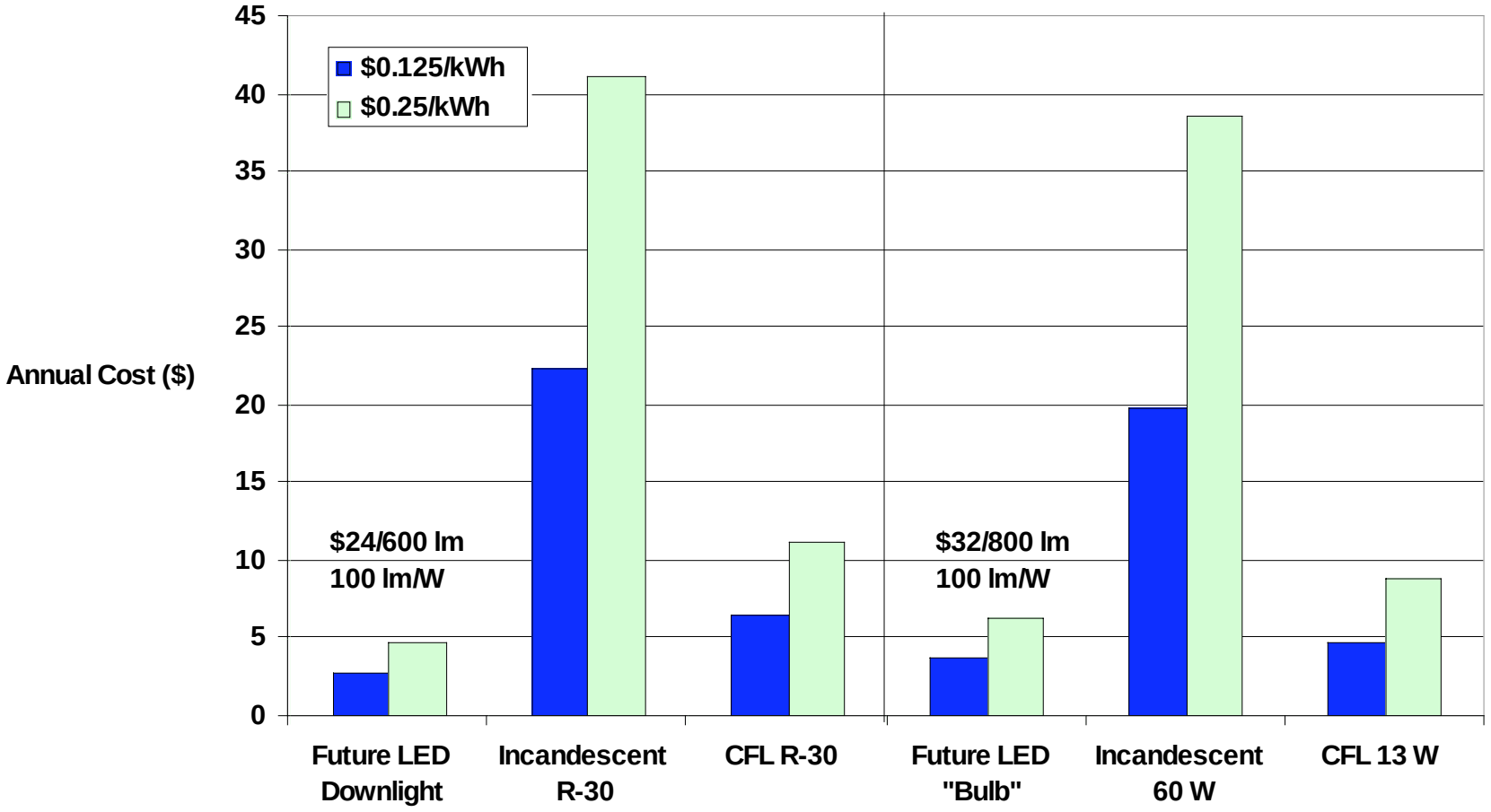
Annual Cost of Lighting (Future)



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Essential Design Principles for LED Light Engines

1. Don’t waste photons
2. Don’t waste electrons
3. Be cool, man

Examples

Efficient Design

Start with 70 lm/W 1-W white LEDs (at 25 °C junction temperature)

Assume: 90% electrical efficiency; 90% optical efficiency; operate at 65 °C junction temperature

Light engine efficacy = 70 x 0.9 x 0.9 x 0.85 = **48 lm/W**

Inefficient Design

Start with 70 lm/W 1-W white LEDs (at 25 °C junction temperature)

Assume: 80% electrical efficiency; 80% optical efficiency; operate at 100 °C junction temperature

Light engine efficacy = 70 x 0.8 x 0.8 x 0.75 = **34 lm/W**

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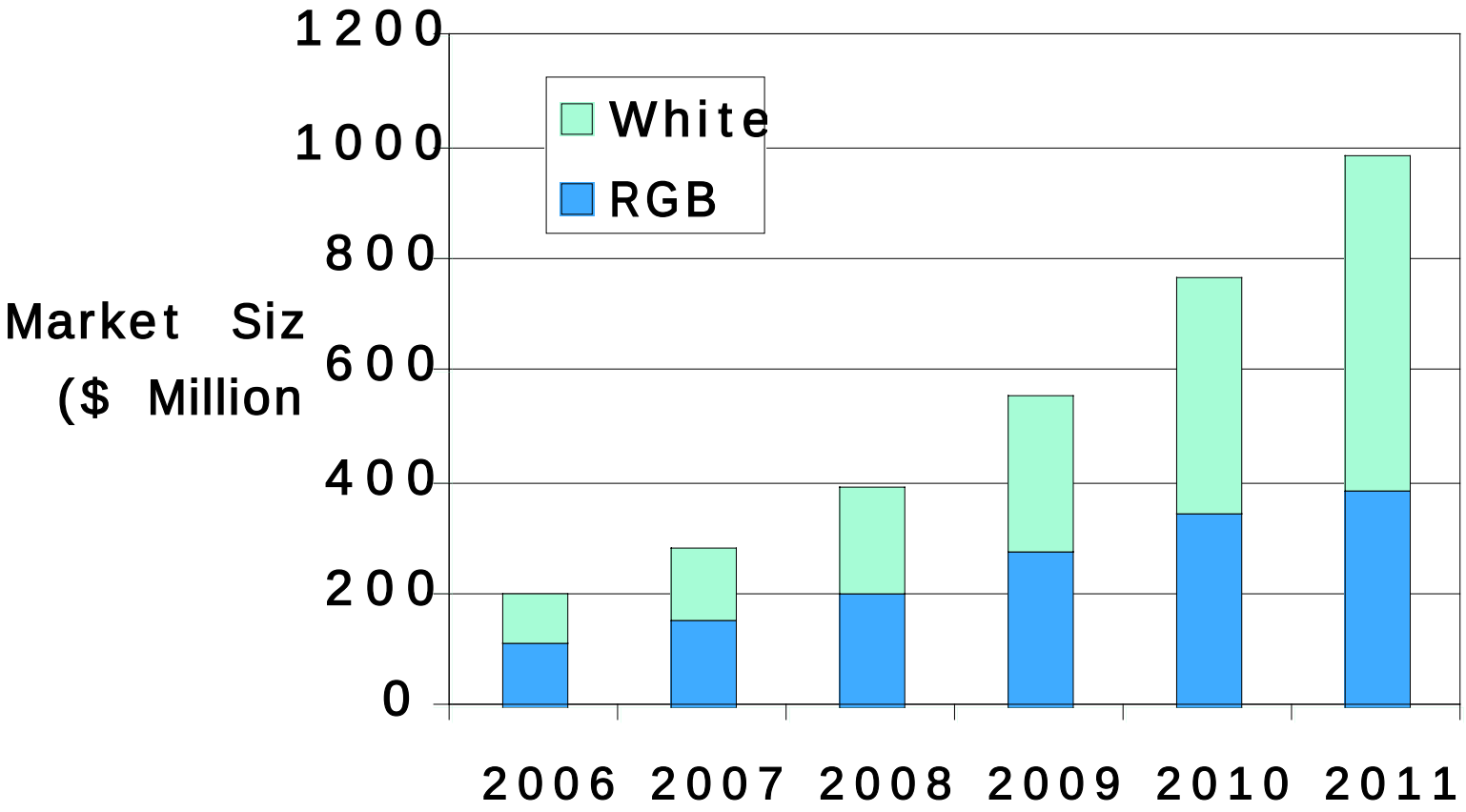
LED Lighting Market Outlook

- Niche lighting applications will continue to grow
- General illumination (e.g. white light applications) will become increasingly important
- Presumes continuing improvement in white LED price/performance
  - And luminaire performance!
- Presumes substantial marketing efforts to penetrate the conventional lighting market
  - Penetration will proceed gradually – application by application
- Overall forecast 37% CAGR to ~$1 billion in 2011

LED Lighting Market Forecast



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Thank you!